Indian Journal of Science and Technology, Vol 8(16), DOI: 10.17485/ijst/2015/v8i16/57499, July 2015 ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Upgraded Spectrum Sensing Method in Cognitive Radio Network

J. Avila* **and K. Thenmozhi**

School of EEE, SASTRA University, Thanjavur - 613401, Tamil Nadu, India; avila@ece.sastra, thenmozhik@ece.sastra.edu

Abstract

Objective: Spectrum sensing ensures reliable detection of primary users and white spaces in the channel such that the cognitive users can utilise the unused spectrum. **Method:** This work concentrates on enhancement in the energy detection based spectrum sensing technique by employing wavelet packet transform in the place of Fast Fourier Transform (FFT) under different wireless channel models. **Result:** They are plotted using MATLAB. Receiver operating characteristics curve concludes that wavelet packet based method overrules the traditional method. **Application:** Free spectrum holes could be found out and efficiently utilized.

Keywords: Cognitive Radio, Energy Detection, Noise Models, Sensing, Wavelet Packets

1. Introduction

Wireless communication involves information transfer by employing the electromagnetic spectrum. The demand for frequency bands in wireless communication has rocketed up in the recent years. Hence efficient utilisation of unauthorised frequency bands is of prime importance[1]. The cognitive radio comes into picture here. Cognitive radio exploits the under-utilized frequency bands by sensing the idle portion in the spectrum to establish communication in an opportunistic manner[2,3].

In cognitive radio the primary users are licensed to use the spectrum bands allocated by Federal Communication Commission (FCC)[4,5], while the secondary users dynamically access the spectrum bands when the primary users are inactive. Spectrum Sensing is the one among the primary functionality of the cognitive radio[6]. It helps to endeavour increased efficiency and utilisation of spectrum. The surrounding environment is scanned for presence of signals in spectrum sensing approach.

Among the different algorithms that have been developed for spectrum sensing this work focuses on energy detection method[7,8]. The major challenge in spectrum sensing is presence of noise in the channel. To achieve fast detection with minimum complexity wavelet packets can be utilised. This paper focuses on the implementation of wavelet packets for spectrum sensing as it overcomes the low accuracy issues with FFT. Instead of dividing the entire spectrum into several orthogonal sub bands like FFT, WPT divides the data among wavelet packet sub bands and multiplex the transmission.

2. Proposed Method

Wavelet Packet Transform (WPT) is the conversion of signal into a series of small wave packets[9] that allows efficient storage of signals than Fourier transform. It serves as an alternate approach for short time Fourier Transform in overcoming resolution problems[10]. It facilitates analysis of signals in both time and frequency domain. Wavelet Packet Transform (WPT) is an extended version of Wavelet Transform (WT). Unlike WT in WPT, both approximation and detail space are exploited, that is the spectrum is divided into finely spaced bands in both higher and lower frequency bands[11].

In WPT, a signal g(t) can be represented as

$$g(t) = \sum_{j \geq j_0} \sum_{l} \left(c_{j,l} \alpha_{j,l} ((t)) + \left(d_{j,l} \beta_{j,l} (t) \right) \right)$$

here

$$c_{j,l} = \langle g(t), \alpha_{j,l}(t) \rangle = \sum_{n} k(n-2l) * c_{j+1,n}$$

*Author for correspondence

$$d_{j,l} = \langle g(t), \beta_{j,l}(t) \rangle = \sum_n k(n-2l) * c_{j+1,n}$$

$c_{j,l}$, $d_{j,l}$ are the scaling and wavelet coefficients respectively. $\langle\,\rangle$ represents inner product of two functions and $\alpha_{j,l}(t)$, $\beta_{j,l}(t)$ are the basis functions of approximation and detailed spaces. The power of the signal can be determined from the formula,

$$P = \frac{1}{T}\int_0^T f(t)^2\, dt$$

Hence for WPT the power is found to be,

$$P = \frac{1}{T}\int_0^T \sum_{j \geq j_o} \sum_l \left(\left(c_{j,l}\alpha_{j,l}(t) \right) + \left(d_{j,l}\beta_{j,l}(t) \right) \right)^2$$

which can be simplified to

$$P = \frac{1}{T}\sum_{j \geq j_0} \sum_l \left(c_{j,l}^2 + d_{j,l}^2 \right)$$

2.1 Energy Detection

Figure 1 gives the block diagram of energy detection method.

The ultimate aim of spectrum sensing is to detect the presence or absence of signal in the frequency band[12,13]. If the prior knowledge of signal is unavailable, then the ideal spectrum sensing technique is energy detection algorithm. Here, in the energy detection technique the signal is discriminated into sub-bands by the detector that performs WPT[14]. In WPT each sub-band's power is obtained and compared with a predetermined threshold value. On exceeding the threshold value the band is identified with live signals else vice versa. This method is commonly used for its lesser computational complexity. However using signal power as parameter leads to false detection as it also considers the noise power.

Assuming q(t) as the received signal, $q(t) = s(t) + f(t)$ where s(t) is the primary user signal and f(t) is Additive White Gaussian Noise (AWGN) sample having a mean value of zero and unit variance σ_f^2.

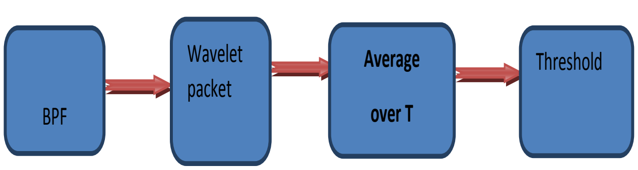


Figure 1. Block diagram of energy detection method.

The primary user detection is based on the following two hypothesis test:

$H_0 = q(t) = f(t)$ presence of spectrum hole.
$H_1 = q(t) = s(t) \otimes h(t) + f(t)$ absence of spectrum hole.

The key statistic T is formulated using,

$$T = \sum_{i=1}^{N} s_i^2 + f_i^2$$

which on comparison with a fixed threshold λ_E, aids in the decision of primary user detection.

2.2 Fading Channels Models

The signal applied to the fading channel undergoes reduction in signal strength during signal transmission. Multipath propagation is the prime reason for fading. The signal received is the ensemble of signal from different paths. The performance of wavelet packet transformed signal in diverse wireless channels is analysed.

2.2.1 Additive White Gaussian Noise (AWGN)

In this channel a random noise signal is added to the signal which provides a simple radio environment for cognitive radio operation[15]. Thus the signal at the receiving end q(t) will be,

$$g(t) = s(t) + f(t)$$

$s(t)$ is the signal and $f(t)$ is the added random signal.

2.2.2 Rayleigh Fading Model

This fading phenomenon is caused primarily due to multipath propagation in the absence of direct of Line of Sight (LOS) between the transmission and the reception terminals. The signal obtained at the receiver is the summation of signals received from various paths when there is no direct LOS between the transmitter and receiver.

Consider $x(t)$ the transmitted signal

$$x(t) = \cos(\omega_c t)$$

here ω_c is the transmitted signal frequency and the received signal s(t) at the receiver is

$$s(t) = \sum_{i=1}^{N} a_i \cos(\omega_c t + \omega_{di} t + \phi_i)$$

here α_i is the amplitude at each path, φ_i is the phase shift in each path and N is the number of paths and ω_{di} is the Doppler frequency of path i representing the Doppler effect when there is a relative motion between the devices.

2.2.3 Rician Fading Model

This model is similar to Rayleigh fading model with an exception of having direct Line of Sight path between the communication devices. Thus there exists a strong dominant component.

The signal received at receiver is

$$s(t)=\sum_{i=1}^{N-1} a_i \cos(\omega_c t+\omega_{di}t+\phi_i)+k_d \cos(\omega_c t+\omega_d t+)$$

k_d is the LOS path strength, ω_{di} is the Doppler shift for indirect path components, ω_d is the Doppler shift for direct path component.

3. Results

Receiver operating characteristics curve giving a comparison between FFT and wavelet packet is shown in Figure 2. From the figure it is clear that wavelet packet overules FFT. For a given probability of detection P_d of 0.2 there is a good improvement in the Signal to Noise Ratio (SNR) in case of wavelet packet method.

Figure 3 depicts the performance of various noise models. For the SNR of –20db the probability of detection of AWGN case is 0.35, whereas for Rayleigh it is 0.27. Rician is in between these two.Rayleigh fading is the worst case because of the severe fading.

Probability of false alarm versus missed detection performance of the three noise models (Rayleigh, AWGN and Rician) are in Figure 4a, 4b and 4c. They are plotted for varying SNR value. Out of three AWGN seems to be better because of non-availability of multipath reflections. Higher the SNR value better is the system performance.

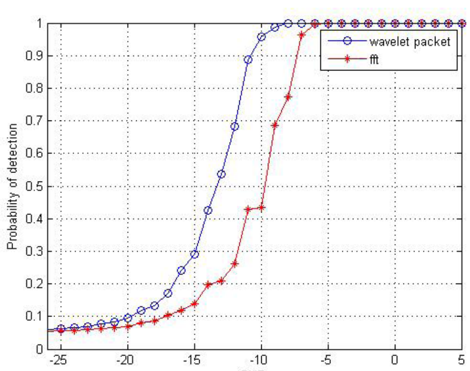


Figure 2. Evaluation between FFT and wavelet packet.

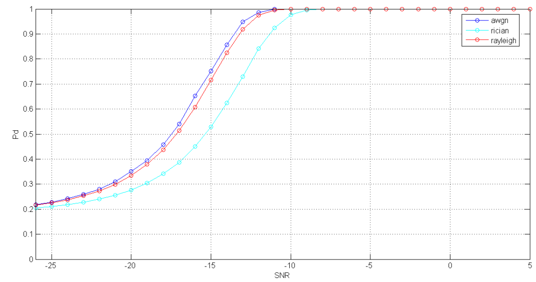
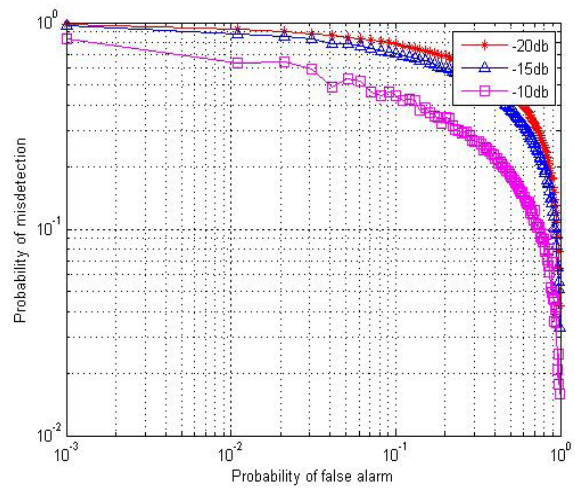
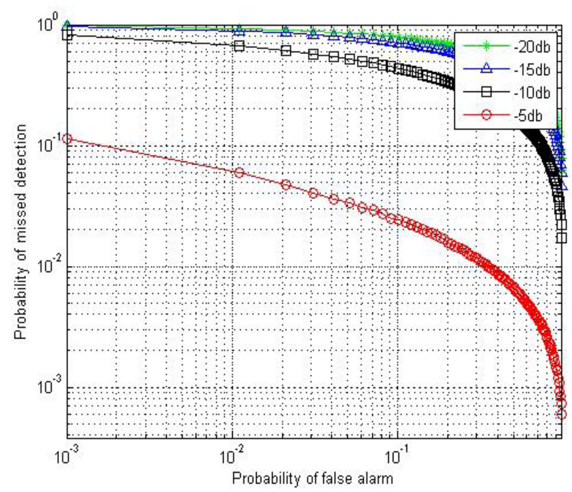


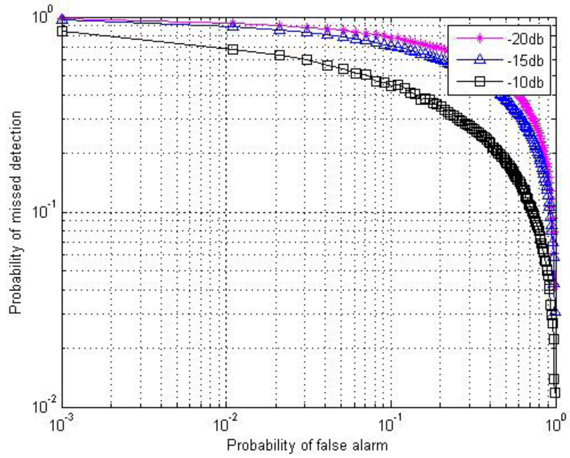
Figure 3. Comparison between nodel models.



(4a)



(4b)



(4c)

Figure 4a, 4b and 4c. Complementary ROC curve for various values of SNR.

4. Conclusion

The detection of spectrum hole by cognitive user is the fundamental requirement in the cognitive radio systems. Thus in this paper, the methodology for improvement in spectrum sensing technique such as energy detection technique using the wavelet packet in different fading channels using MATLAB has been proposed. Simulation results show that the detection of spectrum holes and the primary user is significant using wavelet packet transform over FFT and the spectrum sensing performance under noisy and fading channel conditions.

5. References

1. Bhagavathy Nanthini S, Hemalatha M, Manivannan D, Devasena L. Attacks in cognitive radio networks - A survey. Indian Journal of Science and Technology Communications. 2014; 7(4):530–6.
2. Sindhubargavi R, Yuvasrri Sindhu M, Saravanan R. Spectrum sensing using energy detection technique for cognitive radio networks using PCA technique. Indian Journal of Science and Technology. 2014 Apr; 7(4):40–5.
3. Mitola J III. Cognitive radio: An integrated agent architecture for software defined radio [Doctoral Dissertation]. 2000.
4. Federal Communications Commission. Spectrum Poliy Task Force Report. ET Docket No. 02-135; 2002 Nov.
5. Federal Communication Commission. Facilitating opportunities for flexible, efficient, and reliable spectrum use employing cognitive radio technologies. NPRM and Order. ET Docket No. 03-108. FCC 03-322; 2003 Dec. p. 1–53.
6. Brown TX. An analysis of unlicensed device operation in licensed broadcast service bands. IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks; Baltimore, MD, USA. 2005 Nov 8–11. p. 11–29.
7. Avila J, Praveen E, Varadharajan B. ANN assisted-Augumentation of AIC for MIMO Multiband OFDM System. IEEE International Conference on Advances in Engineering, Science and Management; Nagapattinam, Tamilnadu. 2012 Mar 30–31. p. 228–32.
8. Cabric D, Mishra SM, Brodersen RW. Implantation issues in spectrum sensing for cognitive radios. Proceedings of 38th Conference on Signals, Systems and Computers. 2004 Nov 7–10. p. 772–6.
9. Daubechies ITen lectures on wavelets. Philadelphia, PA: SIAM; 1991.
10. Wickerhauser V. Adapted wavelet analysis from theory to software. Boston: AK Peters; 1994. p. 213–4.
11. Cody MA. The wavelet packet transform. Dr. Dobb's Journal. 1994 Apr; 19(4):44–6.
12. Avila J, Thenmozhi K. Wavelet supersede FFT in MB-OFDM: An effective Cognitive Spectrum Sensing. IJAI. 2012; 5(3):113–21.
13. Avila J, Thenmozhi K. Cognitive (LabVIEW) on FPGA - A novel approach for dynamic spectrum Sensing. International Journal of Electronic Letters. 2015; 3(1)13–23.
14. Digham FF, Alouni MS, Simon Marvin K. On the energy detection of unknown signals over fading channels. IEEE Trans Wireless Comm. 2007 Jan; 55(1):21–4.
15. Babu AS, Rao KVS. Evaluation of BER for AWGN, Rayleigh and Rician Fading Channels under various modulation schemes. International Journal of Computer Applications, 2011 Jul; 26(9):23–8.